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14. ABSTRACT

Development of a simple valve-less meso-scale pump as a physical model for operation of a similar micron-scale pump is discussed. The principle of operation of the pump is based on the differing flow resistance properties of nozzles and diffusers. The cavity, nozzle, diffuser and side reservoirs were fabricated by precision-machining of Lexan. The vibrating diaphragm assembly is a brass thin sheet and a piezoelectric disc that is attached to it thus forming one end of the cavity. Once the operational characteristics of the pump in the form of pressure drop vs. pumped mass flowrate is determined, the data can be compared to the predictions based on a theoretical model.

15. SUBJECT TERMS

Pump, Valve-less, Meso-Scale, Fluid Flow, Nozzle, Diffuser, Piezoelectric.

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DEVELOPMENT OF A VALVE-LESS MESO-SCALE PUMP

Final Technical Report of Contract Number N00014-02-1-1024

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Technical Objective

Development of a simple valve-less meso-scale pump as a physical model for operation of a similar micron-scale pump is pursued.

Technical Approach

For the proposed valve-less pump, a vibrating diaphragm in conjunction with a nozzle and diffuser are the main components. The flow is controlled by utilizing the different flow properties of diffusers and nozzles. During the suction mode (Figure 1), the inlet section acts as a diffuser that has a lower resistance to flow than the outlet section which acts as a nozzle. This results in a larger volume being brought into the pump via the inlet than via the outlet. During the discharge mode, the outlet section acts as a diffuser and the inlet acts as a nozzle, therefore, resulting in a larger amount of fluid being discharged from the outlet than out the inlet. The end result of a single pump cycle is to move a net volume of fluid from the inlet to the outlet of the pump even though fluid moves through the inlet and outlet sections in both directions.

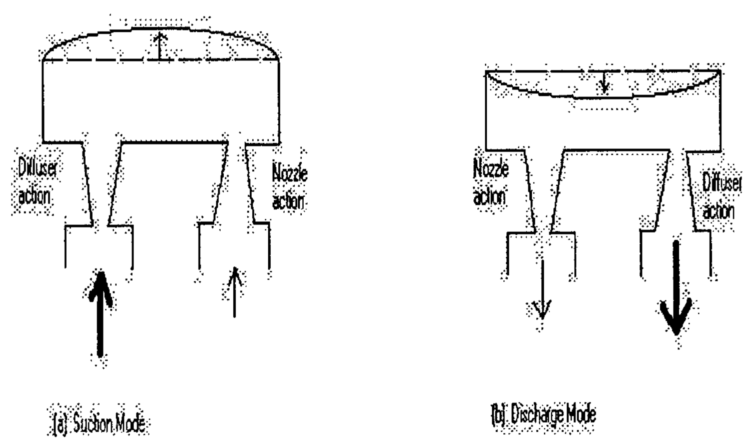


Figure 1 Operation of a Valve-Less Pump

A piezoelectric disc was planned to vibrate the diaphragm that is placed on top of a cavity. The cavity is connected to a nozzle and a diffuser, both of which are two-dimensional passageways for flow. A square-wave voltage generator is used to actuate the piezoelectric diaphragm at approximately the resonance frequency of the system. By performing a simple analysis on the

system utilizing the maximum kinetic and potential energies, it can be shown that the maximum deflection of the diaphragm, and hence maximum flow, will be achieved by operating at resonance frequency. The resonance frequency (f_0) can be calculated utilizing the following equation:

$$f_0 = \frac{1}{2\pi}\left[\frac{K_p(1+\eta^{1/2})^2 b(D-d)}{\rho K_v(\eta+1)L\ln\frac{D}{d}}\right]^{1/2},$$

where K_p and K_v are the diaphragm's spring constant and deflection constant, respectively. Quantities, b, d, D and L are geometric parameters associated with the two-dimensional passageway (diffuser or nozzle). Quantities ρ and η are the density and the ratio of the pressure loss coefficients (always greater than 1).

A displacement transducer was to be placed on top of the diaphragm to monitor the amount of deflection, which will be in the range of micrometers. The pump inlet pressure will be maintained constant and the outlet pressure will be varied to allow determination of pump performance characteristics.

<u>Components of the Pump</u>

The various components of the pump have been designed and fabricated (mainly Lexan). Figure 2 shows a close-up view of the base of the pump. The side with the brass fitting is the receiving end of the pump and the cylindrical cavity of the meso-pump has a diameter of the order of a quarter coin. The side view of the base of the pump is shown in Figure 3. The base is the thickest component and the cavity of the pump is constructed by precision-machining of two thin sheets of Lexan.

Figure 2 Close-Up View of the Base of the Pump

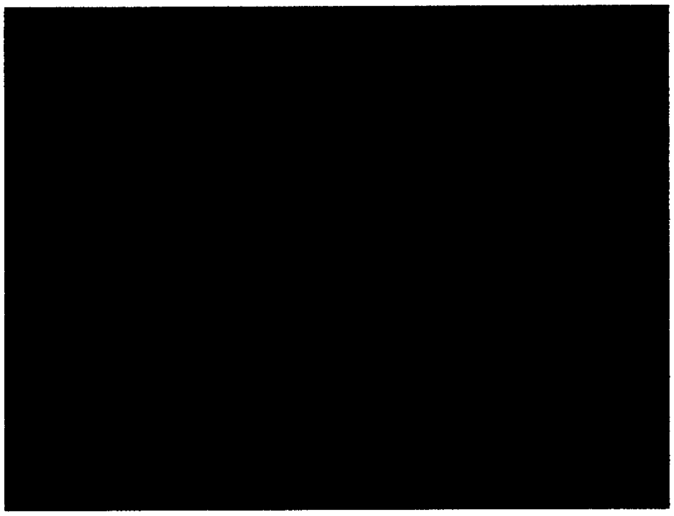


Figure 3 Side View of the Base of the Pump

In Figure 4, the side containers of the pump are shown after assembly. The liquids will be maintained at constant levels in these two containers during the experiments. The height of the opening of the transparent tube that is attached to the brass fitting can be varied in order to control the head of the pump. The fresh fluid that enters the receiving end of the pump will force an equal amount of liquid to leave the container through the brass fitting, thus keeping the water level constant.

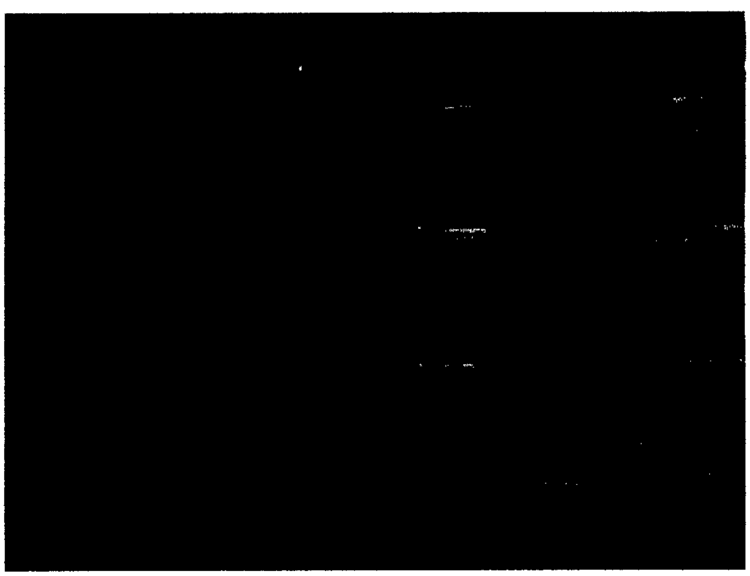


Figure 4 Close-Up View of the Base of the Pump and the Two Reservoirs

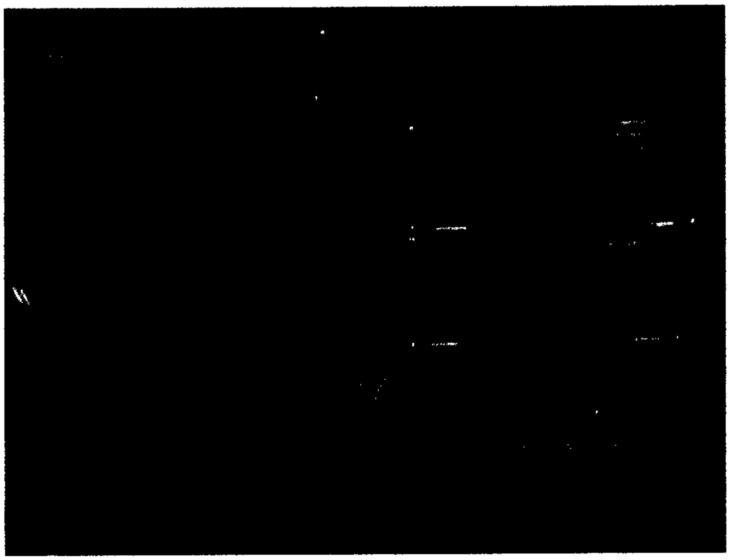
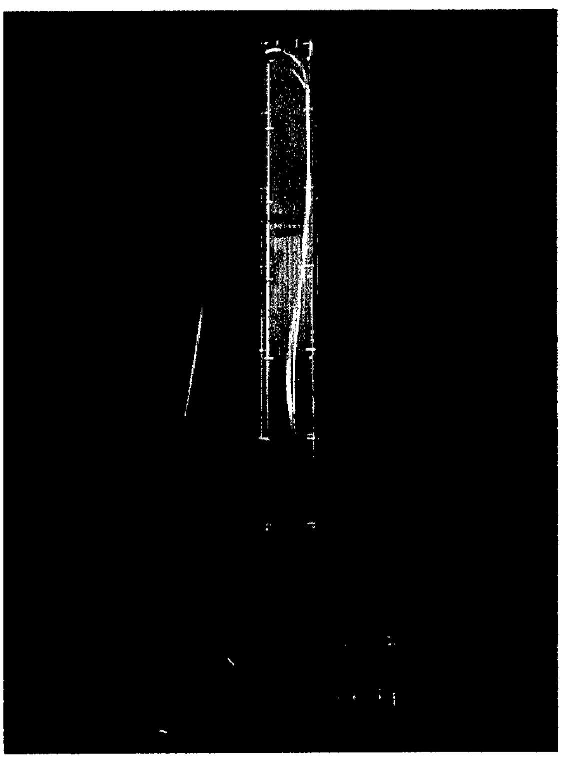


Figure 5 shows the addition of a brass diaphragm and the piezoelectric disc (white disc with a round stripe) to the assembly that was shown in Figure 4. The square brass sheet forms the vibrating boundary of the cavity whereas the piezoelectric disc will cause its vibration upon application of a square-wave signal of known frequency and amplitude.

Figure 5 Close-Up View of the Base of the Pump and the Two Reservoirs plus the Brass Sheet and the Piezoelectric Disc



Another view of the pump assembly is given in Figure 6, showing that the reservoir on the receiving end is about eight (8) times taller than the other reservoir. Determination of the spring constant and the deflection constant of the brass-piezoelectric disc assembly was done using the ANSYS finite-element code. Once this step is performed, the resonance frequency of the system will be determined using the equation given earlier.

Pump performance experiments can commence shortly thereafter by exciting the piezoelectric disc at its resonance frequency and recording the pumped flowrate for a maintained height difference between the two reservoirs. The pumped liquid will be collected from the opening of the brass fitting over a known period of operation.

Figure 6 Distant View of the Pump